FY 2019 Annual Report for
National Program 306 Product Quality and New Uses

Introduction

The USDA-ARS National Program for Product Quality and New Uses (NP306) in 2019 completed the fifth year of its 5-year research plans for the various research projects. Scientists in NP306 continue to demonstrate impact in numerous and diverse areas of research that enhance marketability of agricultural products, increase the availability of healthful foods, develop value-added food/nonfood products, and enable commercially-preferred technologies for post-harvest processing. National Program 306: Product Quality and New Uses, Vision & Relevance can be found at: https://www.ars.usda.gov/nutrition-food-safetyquality/product-quality-and-new-uses/ and includes: the FY2015-2019 Action Plan for NP306.

The overarching goal of NP 306 is to conduct research that develops knowledge and enables commercially-viable technologies to: (1) Measure and maintain/enhance post-harvest product quality, (2) Harvest and process agricultural materials, and (3) Create new value-added products.

By developing commercially viable technologies that maintain/enhance postharvest product quality and create new products, ARS Product Quality and New Uses research increases the demand for agricultural products and, therefore, benefits both agricultural producers and rural communities.

This National Program is organized into three problem areas:
(1) Foods – Problem Areas of research are: 1a. Define, Measure, and Preserve/Enhance/Reduce Attributes that Impact Quality and Marketability; 1b. New Bioactive Ingredients and Health-promoting Foods; 1c. New and Improved Food Processing and Packaging Technologies;

(2) Non-Foods – Problem Areas of research are: 2a. Develop New Post-harvest technologies; 2b. Enable technologies for expanding market applications of existing biobased products, and producing new marketable non-food biobased products derived from agricultural products and byproducts, and estimate the potential economic value of the new products; 2c. Collaborate with breeders and production researchers in the development of both new cultivars/hybrids and new production practices/systems that optimize the quality and production traits of crop-derived products and byproducts for conversion into non-food biobased products;

(3) Biorefining – Problem Areas of research are: 3a. Technologies for producing advanced biofuels (including biodiesel), or other marketable biobased products; 3b. Technologies that reduce risks and increase profitability in existing industrial biorefineries; and 3c. Accurately estimate the economic value of biochemical, thermolysis conversion technologies.

During FY 2019, National Program 306 had 214 full-time scientists and 57 vacancies working at 21 locations across the U.S. actively engaged in 68 ARS-base Projects 103 ARS-led cooperative research projects in NP306. Number of graduate students and postdoctoral students (159). The quality and impact of NP 306 research was further evidenced in 2019 by the following:
• 337 refereed journal articles published
• 17 new patents
• 23 new patent applications
• 25 new invention disclosures submitted
• 7 current cooperative research and development agreements with stakeholders
• 11 new material transfer agreements with stakeholders.

In 2019, NP 306 scientists participated in research collaborations with scientists in 35 different countries: Argentina (1), Australia (4), Austria (1), Belgium (2), Brazil (14), Canada (4), China (15), Colombia (2), Denmark (1), Egypt (1), France (2), Germany (2), Ghana (1), Greece (2), India (2), Israel (3), Italy (4), Japan (3), Kenya (1), Malaysia (1), Mexico (3), Netherlands (2), New Zealand (1), Panama (1), Philippines (3), Singapore (1), Slovakia (1), South Africa (1), South Korea (7), Spain (6), Sweden (1), Tajikistan (1), Thailand (1), Turkey (3), Uganda (1), and United Kingdom (7).

This section summarizes significant and high impact research results that address specific components of the FY 2015 – 2019 action plan for NP 306. Each section summarizes accomplishments of individual research projects in NP 306. Many of the programs summarized for FY 2019 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for USDA-ARS research by rapidly disseminating technology, which enhances the impact of ARS research programs.

Major Accomplishments in 2019

Component 1 – Foods

A natural, sustainable, nonsaturated fat stabilizer for making peanut butter. Peanut butter and other nut and seed butters require the use of a stabilizer to bind the nut or seed oil to prevent it from separating, to improve texture and spreadability, and to allow storage at room temperature. Fully hydrogenated oils or high-saturated (solid at room temperature) fats such as palm oil are often used as stabilizers, but companies are under pressure to replace these unhealthy oils and fats with more natural, sustainable, and healthy alternatives. ARS scientists in Peoria, Illinois, studied the oil binding capacity, long-term stability, and sensory quality of peanut butter stabilized with easily digestible natural waxes, including beeswax, candelilla wax, rice bran wax, and sunflower wax. Wax was able to stabilize peanut butter at 0.5 percent to about 1.5 percent depending on the source of wax and had good long-term stability, and similar texture and mouthfeel compared with peanut butters that contain a hydrogenated oil or saturated fat. This research indicates that food-grade natural waxes could be used as a natural, healthier stabilizer in nut and seed butters and many other food products.

Apple superficial scald: Commercial control strategies. Superficial scald is a browning disorder of apple peels that occurs following postharvest chilling and contributes to fruit quality losses in markets where scald control compounds are restricted. ARS scientists in Wenatchee, Washington, identified gene activity following chilling injury. They found chilling injury is a gene-based cumulative factor that is preventable if apples are exposed to low oxygen, high carbon dioxide (relative to air) storage conditions within 7 days after harvest. Also, they demonstrated that postharvest chilling hot water treatment can effectively control scald. These findings indicate it is possible to use nonchemical control strategies to reduce or eliminate scald from both conventional and organic cold chains within existing commercial storage facilities. These control measures will reduce commodity and economic losses for apple producers, distributers, and retailers for markets where no consistent superficial scald mitigation strategy previously existed.

A new fruit storage clamshell container with superior freshness retention. A new clamshell container for fresh-fruit storage that maintains optimum humidity, prevents fruit weight loss in storage, and does not induce a modified atmosphere, was designed by ARS scientists in Fort Pierce, Florida. The new clamshell has openings in the shell with an opening-to-surface ratio of 0.44 percent in comparison with present-day commercial clamshells with an opening-to-surface ratio of 2.83 percent. The smaller opening ratio, developed over a period of 11 years in 37 experiments, is large enough so that air in the clamshell maintains firmness of sweet cherry stems, and freshness of litchis, strawberries, blueberries, Chinese bayberries, apricots, loquats, and cherry tomatoes. Quality attributes of the packaged fruits were generally maintained more effectively in these ARS-designed clamshells, especially for attributes susceptible to water loss such as shriveling, desiccation-induced browning, and/or drying of pedicels in cherries, calyx of strawberries, pericarp of litchis, peel shriveling of cherry tomatoes, and softening of blueberries and strawberries.

Component 2 – Non-Foods

Microbial-resistant antibiotics that are therapeutic again. Penicillins are a class of antibiotics used to treat a wide range of bacterial infections; however, their effectiveness has been limited over the years with the development of antibiotic-resistant microbes. Tunicamycin is a powerful antibiotic that can be combined with penicillins to overcome this resistance, but its toxicity in human and animals prevents it from being used for therapeutic applications. ARS scientists in Peoria, Illinois, developed a technology to chemically modify tunicamycin into less harmful derivatives while still retaining the ability to enhance penicillins. These methods use solid catalysts developed by the researchers to selectively alter specific chemical bonds in the tunicamycin that were shown to be associated with toxicity. The catalyst is easily removed from the reaction, resulting in a clean, safer tunicamycin derivative that can be used for numerous agricultural applications. This technology will allow stakeholders to potentially reduce the use of traditional antibiotics to treat livestock, which will delay antibiotic resistance, and reinstitute the use of previously shelved antibiotics that had been rendered ineffective due to antimicrobial resistance.

High-performance, ultra-low-viscosity composite base fluids containing biobased oils derived from soy. Composite fluids are obtained by blending petroleum-based oils such as polyalphaolefins (PAOs) with oils derived from vegetables. Blending allows these composite fluids to meet bio-content requirements (e.g., 34 percent for two-cycle engine oil according to the USDA BioPreferred standard) without compromising cost or performance. Biobased polyester fluids synthesized from soybean oil by ARS scientists in Peoria, Illinois, were investigated for their application as ultra-low-viscosity composite fluids. This occurred in collaboration with scientists at Argonne National Laboratory. Ultra-low-viscosity composite fluids are preferred for engine oil formulations because they generate very low friction when sheared, which translates into high fuel efficiency, low fuel consumption, low tailpipe emissions, and improved air quality. The investigation showed that blending up to 40 percent of biobased polyesters with ultra-low-viscosity PAOs caused a very slight change in viscosity. In addition, the composite fluid with 40-percent biobased polyester gave lower friction and more than 10-fold lower wear than either pure PAO or pure vegetable-based polyester oils. This result indicates that successful commercialization of composite fluids will have the potential to generate new markets for soybean and other seed crops.

New cotton plants with elevated oleic acid cottonseed oils. Vegetable oils with high levels of oleic acid are commercially desirable because, unlike low- or non-oleic acid oils, they last longer in deep fat fryers without oxidizing and generating off-flavors. ARS scientists in New Orleans, Louisiana, working with ARS researchers from Starkville, Mississippi, developed cotton plants that have cottonseed oils with elevated oleic acid levels approximately double those of traditional commercial cottonseed oil. The high-oleic-acid trait has been found to be genetically stable. Cotton plant lines will be released to allow breeders to use this germplasm. Based on prior usage of cottonseed oil for frying, regaining this market would represent a substantial gain for the cottonseed oil industry. Assuming a 25 percent higher premium price and a 25 percent market penetration, these elevated oleic acid cottonseed oils would be worth $110 million more than standard low- or non-oleic acid oils.

Washable, reusable, antibacterial cotton wipes. After five machine washes, commercially available textile products containing embedded antibacterial silver nanoparticles that are washed in detergent solutions leach out a significant amount (87 percent) of the total silver in the textiles. ARS scientists in New Orleans, Louisiana, developed a way to embed silver nanoparticles into cotton fiber wipes that retain more than 70 percent of their silver nanoparticles even after 50 machine washes. Silver nanoparticle-embedded cotton fiber wipes are soft, yet they exert powerful antibacterial functions by killing 99.9 percent of the most common bacteria-causing infections. Development of permanent antibacterial cotton wipes has led to two approved invention disclosures: 1) raw white and brown cotton fibers that self-generate silver nanoparticles for wash-durable antibacterial textiles; and 2) fast, reproducible, and heat-free internal synthesis of silver nanoparticles in cotton fiber for wash-durable antibacterial textiles. This technology transfer is supported by the ARS Innovation Fund.

Cotton-based blood clotting (hemostatic) dressings. Excessive bleeding from traumatic wounds is the leading cause of death on the battlefield, and the second-leading cause of death in civilian trauma settings. Materials that promote rapid blood clotting have relevance to both patient survival and optimal recovery. ARS scientists in New Orleans, Louisiana, developed a nonwoven, unbleached cotton dressing that enhances clotting and absorbency for bleeding control. It was commercialized in November 2018. The dressing is 33 percent lighter and 63 percent more absorbent than the standard crinkle-type cotton dressing made with bleached cotton. In addition to having enhanced bleeding control properties, it also resists adhering to damaged tissue and can be torn into small units for easy application. A second generation of this product with 99.99 percent antibacterial activity has now been developed by ARS scientists for prolonged field care and is awaiting U.S. Food and Drug Administration approval. These two cotton dressings fulfill a congressional mandate to use U.S. cotton in textile products used by the Department of Defense. The potential impact of these types of cotton-based hemostatic dressings is to be found in improved dressings used by the Armed Forces and first responders.

A reduced salt-polluting and microbial growth approach to hide preservation. Traditional antibacterial and salt curing of bovine hides generates an effluent that is highly polluting and an environmental issue that plagues the U.S. leather industry. ARS scientists in Wyndmoor, Pennsylvania, created a hide-curing formulation that is low in bactericide, even more effective at limiting microbial growth, and 65 percent lower in salt than the traditional process. This low-bactericide, low-salt formulation reduced effluent pollution by more than 50 percent and the resulting leather was comparable to that made of traditionally cured hides. A Cooperative Research and Development Agreement is being established with a U.S. hide processor to further commercialize this technology.

A new sustainable diesel fuel additive. Due to the development of ultra-low-sulfur diesel fuel, diesel fuel injection systems must tolerate poor lubrication. To aid in lubrication, an additive is required to obtain satisfactory engine performance. Traditional biodiesel is often used for this purpose; however, to be effective, 1 to 2 percent or even more additive is required. ARS scientists in Peoria, Illinois, developed a new additive based on tung oil, a natural compound. The structure of tung oil allows it to be chemically modified with a chemical called maleic anhydride and then further altered by the addition of methanol or butanol. These new additives were studied in diesel fuel at low additive levels, where they were found to be as effective as traditional biodiesel at 20 to 40 times the additive amount. For example, the wear scar and friction results of diesel fuel laboratory tests were found to be improved by 40 percent and 46 percent, respectively, at only 500 ppm additive levels of the new additives. Other oils such as polyalphaolefin have also been evaluated, and the additive is effective in those oils as well.

Component 3 – Biorefining

New bioreactor technology improves cellulosic ethanol production using an ARS patented yeast strain. Current cellulosic ethanol conversion from lignocellulosic materials requires the extra expense of hydrolytic (digestive) enzymes to release fermentable sugars that produce ethanol. Reducing the expense of digestive enzymes is vital for sustainable, cost-effective ethanol production from lignocellulosic biomass. An ARS scientist in Peoria, Illinois, developed a new yeast strain, Clavispora NRRL Y-50464, that produces beta-glucosidase which converts cellulosic ethanol from corn stover. Conventional bioreactors designed for traditional liquid fermentation are not suitable for cellulosic ethanol production using the simultaneous saccharification and fermentation (SSF) processes. ARS in collaboration with East China University of Science and Technology researchers demonstrated a 19 percent increase in cellulosic ethanol production using corn stover through an approach called "process engineering" within SSF processing. The bioreactor was designed to provide enough mixing power and mass transfer capability during enzymatic hydrolysis to achieve higher levels of cellulosic ethanol production and reduced the enzymatic cost by 4 percent needed for SSF ethanol production. The outcome of this study affects the renewable bioenergy community and the academic and industrial sectors and provides a reference and guideline for continued improvement of low-cost cellulosic ethanol production from lignocellulosic materials.

Efficient production of itaconic acid by a fungus not inhibited by biomass metal ions. Itaconic acid (a building block chemical with a variety of industrial applications) is currently industrially produced from glucose using fungal fermentation. In order to expand the use of itaconic acid, an understating of efficiency limitations and production costs is needed. Waste agricultural residues have the potential to serve as a low-cost source of sugars for itaconic acid production, but ARS researchers in Peoria, Illinois, found that metal ions in this biomass greatly inhibit efficient itaconic acid production. These ARS researchers discovered a novel fungus (*Aspergillus terreus*) was able to tolerate metal ions during fermentation-production of itaconic acid. This fungus is expected to perform well in commercial fermentation production of itaconic acid even in the presence of metal ions to provide efficient, complete conversion of this acid.

Low-cost production of high-value plant-based xylitol. Xylitol is a naturally occurring sweetener that has 40 percent fewer calories than table sugar and has been shown to improve dental health and prevent ear infections. These desirable health-related attributes support the use of xylitol in pharmaceutical and personal-care products, and as an alternative sweetener in gums and mints. Xylitol is difficult to extract from natural sources and, because the current petroleum-based chemical method of production has high energy and cost demands, a simpler, cheaper, biological route to xylitol processing is preferred. ARS scientists in Peoria, Illinois, determined the effect of several factors on xylitol processing using an inexpensive microbe that makes xylitol from the sugar xylose found in renewable plant biomass. This microbe is resistant to inhibitors of the types encountered in bioprocessing of biomass into fuels and chemicals, and xylitol production from fibrous biomass is a new use of agricultural-harvesting residues that are typically viewed as low-value or waste material.

Improved alcohol tolerance by alcohol-producing bacteria. Although yeasts are traditionally used to produce corn sugar-based ethanol, bacterial strains are better utilized to ferment mixed sugars or to synthesize alternative biofuels such as butanol. Most bacteria are inhibited by the presence of alcohols, which limits their ability to synthesize alcohol, especially under conditions of high alcohol. ARS scientists in Peoria, Illinois, developed a technology that significantly improves the alcohol tolerance of bacteria. They identified two bacterial strains found in wineries and fuel ethanol facilities that survive high concentrations of ethanol. They then compared the genomes of these alcohol-tolerant bacteria with other similar strains that were sensitive and found two genes unique to the alcohol-tolerant isolates that are often associated with this alcohol-feedback-inhibition (stress) response. These genes were each expressed in alcohol-stressed bacteria and shown to confer higher tolerance to ethanol and butanol. The potential application of this research will lead to more efficient production strains of bacteria that will benefit fuel ethanol producers.

Protein expression analysis revealed a fine-tuned mechanism of in situ detoxification pathway for ARS-tolerant industrial yeast. Overcoming the toxic compounds associated with lignocellulose-to-biofuels conversion poses significant challenges to developing new strain for a sustainable biobased economy. An ARS scientist in Peoria, Illinois, discovered that the stress-tolerant industrial yeast *Saccharomyces cerevisiae* (obtained by adaptation) can detoxify aldehydes, including furan aldehydes and some phenolic aldehydes, a major class of inhibitory chemicals derived during lignocellulose-biomass pretreatment. Extensive studies of *S. cerevisiae* tolerance to aldehydes have been carried out; however, limited proteomic evidence is available on yeast tolerance mechanisms. Using comparative time-course studies of yeast protein-profile expression in response to synergistic inhibitor challenges, a key protein, glucose-6-phosphate dehydrogenase (Zwf1p), was revealed, which is required for detoxification. Outcomes of this research will facilitate development of next-generation biocatalysts for sustainable production of biofuels and biochemicals from lignocellulosic feedstocks. This new proteomic-based insight into yeast adaptation supports both basic research and applied industrial investigations.